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Thermal comfort in desert refugee camps

D. Albadra, M. Vellei, D. Coley, J. Hart*

Department of Architecture and Civil engineering, University of Bath, UK

*Department of Social and Policy Sciences, University of Bath, UK

Abstract

Long-term encampment is a growing aspect of a growing refugee crisis. There is hence the need to ensure shelters provide a safe and suitable environment. We present the first field study including social and thermal comfort surveys and physical measurements conducted in Syrian refugee camps in Jordan, during summer and winter. This required the creation of a new Arabic thermal comfort survey based on the numerical ASHRAE scales to ensure the elimination of any ambiguities due to translating the scales. The three analysis methods used (linear, logistic and multiple logistic regression) all gave the same neutral temperature, 23°C; however, Fanger's predicted mean vote model was found to underestimate the adaptive potential of the refugees. The comfort band found using logistic regression ranged from 28.4°C to 17.2°C, suggesting a significant adaptability of the refugees, but not one equal to the temperature range found on site. Issues with the clash between ventilation, privacy, security and sand ingress were identified, and this points to a need to re-evaluate shelter ventilation in general. However, given the extreme conditions recorded, natural cross ventilation alone will not be sufficient in achieving summer comfort. Combining this with the observation that, due to safety and lack of resource, the refugees have no means of heating at night, a shelter solution that successfully includes insulation, and possibly thermal mass would seem important.

Keywords

Thermal comfort, Refugee camps, Arabic survey, Field study, Jordan

Abbreviations

TSV thermal sensation vote

TPV thermal preference vote

PMV predicted mean vote

Nomenclature

T_n Neutral temperature

T_o Operative temperature

I_{cl} Clothing insulation

V_a Air velocity

T_a Air temperature

T_g Globe temperature

1. Introduction

According to the United Nations Refugees Agency UNHCR, we are currently witnessing the worst refugee crisis recorded [1]. As of the end of 2014 there were over eight million people living in encampments as a result of armed conflicts [2]. In addition, over nineteen million new people were displaced due to natural hazards in 2015 alone [3]. These are not short term displacements: at the end of 2014 there were people living in conditions of internal displacement for over ten years in nearly 90% of the sixty monitored countries [4]. Similarly, major refugee situations last nearly two decades on average [5].

In comparison to issues such as food, water and medical care, shelter design and performance is understudied and rarely evaluated, despite it being known that prolonged exposure to extreme thermal conditions can lead to morbidity and mortality [6]. The shelters provided by humanitarian agencies are generally lightweight structures and are ineffective against high summer temperatures, or winters where temperatures can plunge well below freezing. The struggle to cope with such adverse conditions only adds to the psychological burden of people coming to terms with the loss of loved ones, community and property. In order to inform future shelter design, it is therefore important to understand both the current conditions in such camps and the thermal comfort limits and preferences of the targeted population.

In this paper we assess for the first time thermal comfort in desert refugee camps via social and thermal comfort surveys, and physical measurements. The objectives of this paper are to: 1) assess the environmental conditions, 2) discover common thermal adaptation methods, 3) assess priorities and needs in terms of shelter design, 4) evaluate the refugees' thermal preferences, comfort limits and establish their neutral temperature. In addition, we develop and test a new approach to the ASHRAE comfort scales designed specifically for translation into any language, including use with illiterate populations, and publish the first comfort survey in Arabic.

2. Adaptive thermal comfort theory

Two approaches to human thermal comfort have evolved over the past half a century. The steady state approach, pioneered by Fanger in the late 1960s [7]; and the adaptive approach introduced by Nicol and Humphreys in the 1970s [8]. Both allow the thermal environment experienced by a population to be measured by asking occupants to score their environment (a process termed voting) on the same 7-point *thermal sensation* scale (from cold to hot). The steady state approach assumes that any degree of thermal stress, and consequently any effort to adjust to it, is undesirable [9]. Thus, Fanger developed an index to predict the mean *thermal sensation* vote of a population based on the heat balance of the human body, and termed this the Predicted Mean Vote (PMV) [7]. This index was derived through research in climate chambers and resulted in a defined narrow thermal comfort zone that served the needs of the air-conditioning industry and was therefore mainly intended for application in conditioned spaces. On the other hand, the adaptive approach considers physiological (acclimatisation), behavioural (adjustment) and psychological adaptation (habituation and

expectation) [10]. It demonstrated through field surveys that people living in naturally ventilated buildings were satisfied at a much wider range of temperatures than those found in conditioned buildings [10] [11]. The approach did not aim to determine an optimum set of indoor environmental variables but rather to define a band of temperature within which an occupant can find his or her own optimum given sufficient adaptive opportunities, for example removing a jacket, or opening a window. A key feature of the approach is that it predicts that the temperature people are comfortable at (termed the comfort or neutral temperature) is a function of the outdoor air temperature over recent days [12].

Assessing thermal comfort through field studies where occupants are questioned about their comfort is now a common practice across the world, for example, in: Japan [13], Malaysia [14], Nepal [15], UK [16], Australia [17], the USA [18], India [19], Libya [20], Tunisia [21], and Iran [22]. Indeed the ASHRAE-55-2004 to 2013 [23] adaptive thermal comfort standards are based on results obtained through field comfort surveys. However, no robust research on thermal comfort has been carried out in refugee camps that are composed of temporary shelters—which can end up being inhabited for decades. Such camps tend to be placed in inhospitable environments with extreme climatic conditions. Their inhabitants are displaced, invariably foreign to the camp's location/climate, and its accommodation. A recent study [24] demonstrated that it is hard for migrating populations to adapt to environments that are less thermally comfortable or of lesser quality than their long term thermal history.

3. The surveyed camps

The two camps studied are sited in northern Jordan in a desert hot and dry climate [25]. Since 2011 the Syrian crisis has resulted in a mass displacement of people, and Jordan currently hosts 664,100 Syrian refugees: around 80,000 of those are housed in the Zaatari camp and 54,000 in the Azraq camp [26]. In Zaatari the mean maximum outdoor temperature is 32.7°C and the mean minimum is 1.9°C. In Azraq the mean maximum outdoor temperature is 36°C and the mean minimum is 2.8°C [27].

Zaatari (32.29° N, 36.33° E) consists of caravan-like structures (which replaced tents). 11% of these are static caravans with screed flooring with the walls and roofs made of 40mm polyurethane insulated sandwich panel with inner and outer surfaces of 0.35mm steel sheet (G. Barakat, personal communication). The remaining 'mobile' caravans are also made of insulated sandwich panels, however they sometimes have timber inner surfaces and a suspended timber floor, which in some cases has been replaced by the refugees with a screed of cement mortar over rubble (Figure 1, right). None of the designs were developed after completing a survey of the physical or social preferences of the population; hence, for example, low level windows allow passing males to see into female areas. This means windows become occluded, reducing ventilation rates. However, unlike Azraq, occupants and caravans can relocate to ensure occupants are in a neighbourhood in which they have family.

Azraq camp (31.91° N, 36.59° E) was pre-planned, and 13,500 shelters were built of corrugated metal sheeting separated by 10mm of foam-based insulation (Figure 1, left). Picking up on some of the lessons learnt at Zaatari, the shelters were designed "to maximise

privacy and protect against severe weather conditions” [28]. The need for privacy led to a design with only one window and high level openings consisting of short lengths of 152mm waste pipes on the gables, thereby restricting the ability to cross ventilate. In addition, the design drawings show numerous cold bridges with the potential to form points of condensation, and thermal by-pass due to loose insulation. This has probably resulted in a significant failing of the design; a qualitative assessment of the Azraq camp conducted by REACH in 2015 confirms this, as it was found that 90.2% of 600 respondents were unsatisfied or very unsatisfied by the temperature in their shelters in summer and 44.8% were unsatisfied or very unsatisfied by the temperature in their shelters in winter [29].



Figure 1: Azraq camp (left) notice the camp follows a grid layout, Zaatari camp (right) caravans are randomly arranged as suits the refugees. (Photo: S.Coley.)

4. Methodology

A thermal comfort survey, including spot measurements of environmental parameters, was conducted directly in a Levantine Arabic dialect similar to that spoken by the refugees. In addition, a social survey was conducted to record the views of refugee families on shelter design, adaptation methods, satisfaction and preferences. The surveys were completed in late summer (31st of August to 23rd of September 2016) and winter (2nd to 22nd of January 2017) between 9:30am and 3:00pm.

4.1 Data collection

The families were selected randomly. Given the range of backgrounds, intra-household dynamics, education and literacy levels, all surveys were administered through interview. The questions were explained in detail in order to guarantee common understanding amongst occupants. The summer survey consisted of 75 families (38 families in Azraq and 37 families in Zaatari). Fifty-six of the 75 families were visited again for the winter survey, and an additional 24 families were interviewed in winter to compensate for those who were not available. The respondents were interviewed in their residence (shelters). First, the respondents as a family unit were asked to answer the social survey questionnaire; all family members present discussed the questions and one response per family per season was recorded as the main interest of the social survey was to find out, what aspects of the shelter design worked (or didn't) for them as a family. This took about twenty minutes allowing them

to physically acclimatise in case they were doing other activities prior to the survey. Then they were asked individually about their thermal sensation and thermal preference while spot measurements of indoor environmental variables were recorded using hand-held devices at 1m high. Respondents' height, weight, age, clothing level, and activity level, were noted.

A weather station was established in Zaatari during the summer survey and in Zaatari and Azraq during the winter survey. The weather station in both locations was set up on a tripod 2.5m high on the roof of UNHCR office caravan located within the camps. The sample period of air temperature, relative humidity (RH) and global solar radiation onto the horizontal measurement was one minute with averages recorded every 30 minutes. Wind speed and direction were recorded at one minute intervals. (see table A1 in appendix A for details of the instrumentation).

4.1.1 Sampling method for the thermal comfort survey

There are two common sampling methods when conducting thermal comfort surveys, transverse and longitudinal. In the former, large numbers of individuals are used, with the survey being completed once. In the latter, which is more common, a smaller sample are repeatedly surveyed over a long period of time in order to cover a large range of temperatures. Ensuring a large range in air temperature is known to be important in such work [30]. The number of data points (responses) collected varies significantly in the literature. For example, Luo et al., [31] obtained 834 points from 50 individuals, Sharma and Ali [32] obtained a total of 5100 from 18 individuals, Mustapa et al., [33], collected 303 from 28 individuals and Indraganti and Rao [34] collected 3962 responses from 100 individuals. In a transverse survey, Ogbonna and Harris, [35] had a sample size of 200 subjects, Feriadi and Wong, [36] had 525 subjects.

In this study, due to security restrictions and the nature of the survey that mandated interviewing the individuals, a repeated transverse survey was used. In total 336 datasets were collected over the summer and winter from 270 individuals from 99 households across both camps, and a range of indoor air temperatures from 12°C to 37°C was achieved.

4.1.2 Scales and terminology

The thermal comfort scales were the standard 7-point ASHRAE *thermal sensation scale* and the 5-point *thermal preference scale*. The thermal sensation scale records an occupant's Thermal Sensation Vote (TSV) on a scale of (hot to cold), while the thermal preference scale asks the occupant what their preferred sensation is (Thermal Preference Vote, TPV) at that moment, from much cooler to much warmer. The ASHRAE scales uses the terminology 'neutral', 'slightly warm', 'warm', 'hot', 'slightly cool', 'cool', and 'cold' for TSV, and 'no change', 'a bit cooler', 'much cooler', 'a bit warmer' and 'much warmer' for TPV. The word 'warm' in standard Arabic and Levantine Arabic dialect - *dafi* - has a positive meaning, i.e. to be warm is a positive sensation and is never used in a summer context. In a winter context, being warm is understood as being comfortable. To imply a negative warm sensation, the equivalent of the word 'hot' is used, i.e. (*moshaweb*) On the other hand, there is no equivalent to the word 'cool' in Arabic, only 'cold', (*barred*), which is a negative sensation. This was especially problematic as demonstrated during a pilot of two families in Azraq in the hot season when respondents were asked whether they preferred their environment to be 'a bit' or 'much colder'

in Arabic as opposed to the English 'a bit or much cooler'. The respondents were confused and gave answers along the lines of "I prefer the weather to be nicer but not cold as in winter". Studies in Japan [37] and Nepal [15] highlighted similar issues when conducting a thermal comfort survey using local languages. In this study, in order to address such issues, the respondents were first asked whether they felt absolutely neutral (*hiyadi*) or felt a sensation of heat or cold. If they answered neutral, (*hiyadi*), their thermal sensation was registered as such. If they said they felt a discomfort or sensation of heat or cold, then they were asked to say on a scale 1 to 3 how hot or cold they felt with 1 being a little bit, and 3 being too much. A similar numerical approach was used for the thermal preference scale.

4.2 Calculation of indices

4.2.1 Operative temperature

The expression of comfort by an individual is related to the operative temperature (which is a combination of the air and radiant temperatures and the air speed). Using the recorded measurements of air temperature, globe temperature and air speed, the operative temperature was calculated using equation (1) provided in ISO 7726 [38]:

$$T_o = \frac{T_r + (T_a \cdot \sqrt{10V})}{1 + \sqrt{10V}} \quad (1)$$

where T_r is the mean radiant temperature, T_a the air temperature and V the air speed. The measured globe temperature T_g was used to represent the mean radiant temperature (T_r) as suggested by Nicol et al., [39], given the likely error in measuring T_r .

4.2.2 Metabolic rate and clothing insulation

Metabolic rate was estimated using tables available in ASHRAE 55, based on the subject's activity observed during the 15 minutes prior to the start of the questionnaire. Total clothing insulation values I_{cl} are expressed in clo units. The ASHRAE 55 and ISO 9920 standards [40] include tables of insulation values for common clothing ensembles in the western world, but more recently values for Asian and Middle Eastern communities were proposed in [41], [42]. Although the refugees clothing shared a few characteristics with these gulf and Middle Eastern ensembles, for example the Hijab or headscarf, other aspects of the ensembles were significantly different. For example, in summer, the majority of men wore western style trousers and t-shirts, while a few wore traditional head wear, with either western clothes or the traditional long dresses, see Figure 3, as opposed to the thinner headwear and white dress suggested in [41]. Women on the other hand, wore a headscarf and floor length, long sleeved, coloured dresses, and underneath wore a pair of pyjamas, leggings or thin cotton trousers. In winter, both males and females wore several layers of clothing when inside their shelters, including jackets (Figure 2). In order to calculate the most representative clothing insulation values, in most cases the closest ensemble available was used, mainly those provided in [42], and then the value of available garments insulation was subtracted or added to it as shown in Table 1.

Table 1: Examples of refugee clothing insulation.

Al Ajami et al., 2008 'islamic dress'			Calculated refugee clothing (minimum values)	
	ensemble	I_{cl} (clo)	ensemble	I_{cl} (clo)
Women Summer	Bra, pants, sandals, long dress, hijab	0.8	Bra, pants, long bottoms, long dress, hijab, barefoot	0.93
Women Winter	Bra, pants, shoes, socks, thicker dress, hijab	1.15	Bra, pants, long bottoms, long sleeve blouse, thicker dress	1.43
Men Summer	T-shirt, short bottoms, long dress, sandals, headwear	0.69	Men western style clothing: Men briefs, t-shirt, short sleeve blouse, trousers	0.43
Men Winter	T-shirt, short bottoms, long serwal (bottoms), long dress, socks, shoes, headwear	0.79	Men western style clothing: Men briefs, t-shirt, long sleeve sweater, thick trousers, socks	0.75



Figure 2: Examples of indoor winter clothing. It is clear that occupants wore several layers to keep warm. (Photo: S. Coley)



Figure 3: Examples of indoor summer clothing. Men had a greater flexibility than women in adapting their clothing between seasons.

4.2.3 The predicted mean vote model

The adaptive comfort model uses a questionnaire to obtain the occupants' actual thermal sensation votes while recording indoor environmental variables. By contrast, the Predicted Mean Vote (PMV) model developed by Fanger predicts an occupant sensation vote based on the heat balance of the human body taking into account indoor environmental variables and the influence of clothing and metabolic rate [43]:

$$PMV = (0.303 e^{-0.036M} + 0.028) L \quad (2)$$

where M is metabolic rate and L the thermal load. (This is defined as the difference between the internal heat production and the heat loss to the actual environment.)

The PMV of each individual was calculated using a visual basic routine [44] based on guidance and equations available in ISO-7730 [43].

4.3 Regression methods

Given that the votes and spot measurements of the environmental variables in the dwellings were recorded simultaneously, regression can be used to estimate the temperature at which a population will feel neutral and the range of temperatures the majority (80%) are likely to feel comfortable over. Simple and multiple linear regressions are the most widely used methods for modelling occupant thermal sensation in field studies [10, 11, 13, 19, 33, 45-52]. In our case, the simple linear regression method consists of plotting the TSV recorded from the refugees against the indoor operative temperature (T_o) and drawing the regression line; the neutral temperature (T_n) is then the temperature corresponding to a mean TSV of zero [29]:

$$TSV = a T_o + b \quad (3)$$

and

$$T_n = -b/a . \quad (4)$$

The surveyed data was collated into 1°C intervals before the regression was completed, in line with [10].

The gradient, α , of the linear regression indicates the temperature perturbation needed for a change of 1 unit in TSV. It is therefore a measure of occupant sensitivity to indoor temperature changes and gives the degree to which a population is able to adapt to changes in the thermal environment. Less steep gradients are indicative of a larger range of temperatures (termed the comfort band) over which occupants consider themselves to be comfortable, and can be associated with more effectively adapted and less sensitive occupants who are able to tolerate exposure to a wider range of indoor operative temperatures [19] [53].

Similarly, T_n can be obtained through a simple linear regression using the TPVs of the whole population instead of the TSVs. This is known as the preferred neutral temperature and it is sometimes argued that it is a more appropriate indication of the optimum comfort temperature [10].

However, there are some statistical issues in the use of linear regression in thermal comfort research. Such issues arise from modelling an ordinal response, such as TSV, using a continuous model [54] in addition to the extreme simplicity of the linear model. Hence, several works propose logistic regression as an alternative [55]. Multinomial logistic regression [56] predicts the probability of a dependent variable, in our case TSV or TPV, which can take more than two values, given the value of a predictor variable, in our case T_o :

$$\ln\left(\frac{P(TSV)}{1-P(TSV)}\right) = \beta_0 + \beta_1 T_o \quad (5)$$

and similarly for $P(TSV)$. Equation (5) is,

$$P(TSV) = \frac{e^{\beta_0 + \beta_1 T_o}}{1 + e^{\beta_0 + \beta_1 T_o}} . \quad (6)$$

In this case, the neutral temperature can be interpreted as the temperature corresponding to the highest probability of having a neutral TSV (i.e. a TSV between -1 and 1).

Both the linear and logistic regression assume that the only variable with influence over TSV is the operative temperature. Given other variables were included in the measurements made in the shelters and of the occupants, it is natural to ask if any of these influenced the thermal sensation or thermal preference votes of the refugees, and if so, by how much. Multiple logistic regression expands equation (5) to include K potential influences X_1 to X_K :

$$\ln\left(\frac{P(TSV)}{1-P(TSV)}\right) = \beta_0 + \beta_1 X_1 + \beta_2 X_2 + \dots + \beta_K X_K \quad (7)$$

Examples of influences would be the air temperature, the relative humidity and the clothing level of the refugees.

We use all three forms of regression to analyse the data from the thermal comfort surveys in the camps. The Mann–Whitney U test is used to compare differences between samples and the significance level is 0.05.

5. Results and discussion

5.1 Social survey

The average number of members per household was 6.2. It was found that 87% of respondents had adapted their shelter (Figure 4 a, b). The most common adaptations to the shelters were expanding the shelter by lightweight structures such as fabric or metal sheeting. Over 35% of families cut an additional window in Azraq while less than 5% did the same in Zaatari. Moreover, it was observed that the high-level pipe openings provided for ventilation in Azraq shelters tended to be blocked by residents to eliminate sand ingress in summer and cold draughts in winter. Provision of security and safety was cited as the most important aspect in the design of a shelter, followed by thermal comfort then privacy (Figure 5). In Azraq, which suffers from harsher summers, the provision of thermal comfort was cited by 22% of respondents as the most important aspect in shelter design, and as the second most important by 44%, compared to 25% and 28% respectively in Zaatari. In addition, families were asked to rank their satisfaction with certain aspects of their shelter from (1) to (5) with (1) being very unsatisfied and (5) being very satisfied. The majority of families reported that they found their shelters to be unbearably hot in July and August, while they also found it freezing in winters especially at nights. Overall, 85% of the families were unsatisfied or very unsatisfied with the thermal conditions in summer while only 33% said the same in winter (Figure 6). However, in Azraq 100% of families said they were unsatisfied or very unsatisfied with the thermal conditions in summer compared to 18% in winter. While in Zaatari, the percentage of unsatisfied/very unsatisfied families in winter was 48% compared to 73% in summer. With regards to safety/security, 75% of the families were satisfied or very satisfied with the safety of their shelters.



Figure 4: (a) Zaatari: caravans adapted by covering the area between the shelters and pouring a concrete floor in the interior covered court-yard. (b) Azraq: adaptation by enclosing the outside and adding an interior layer of aluminium foam insulation.

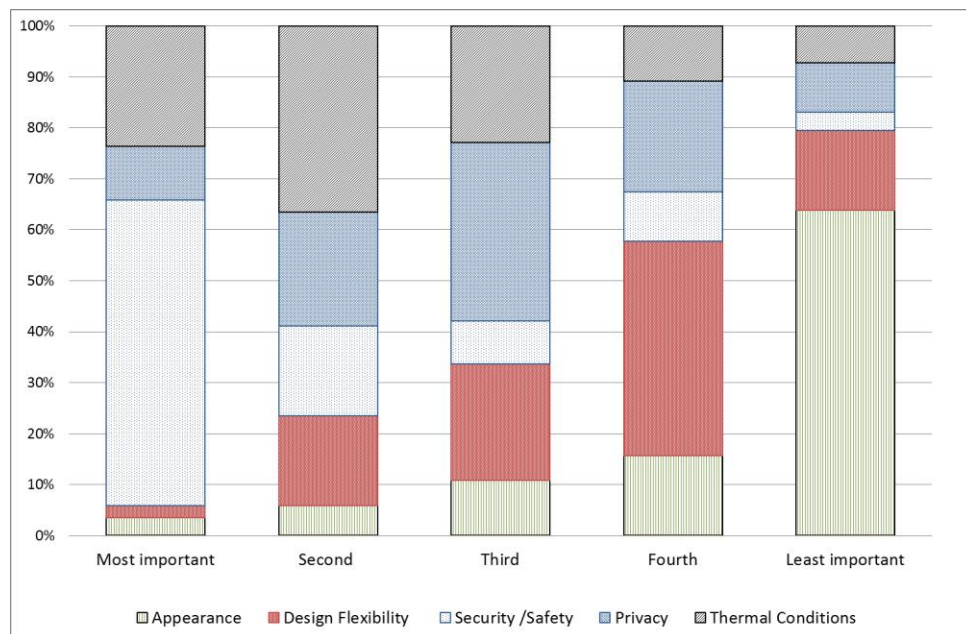


Figure 5: Ranking of design considerations from the social survey; several families were only able to point out their first two priorities and were not able to rank their remaining preferences.

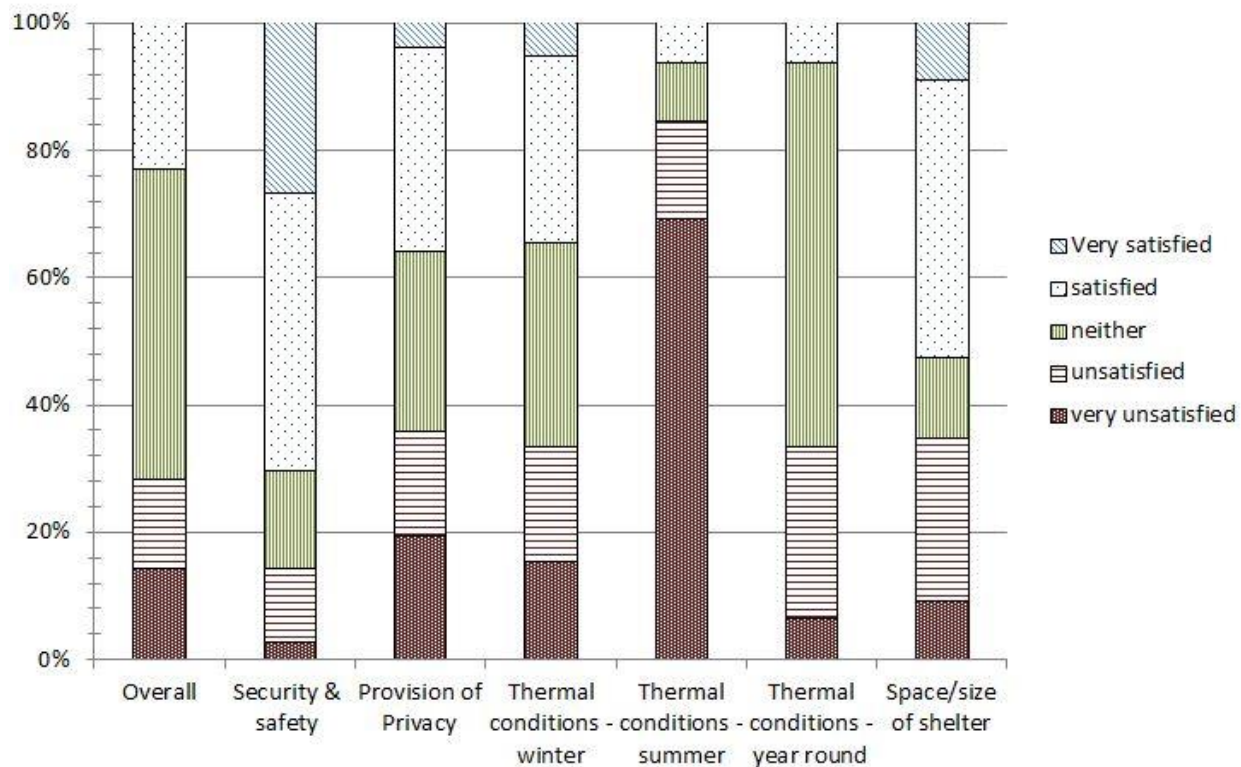


Figure 6: Satisfaction with basic shelter parameters from the social survey.

5.2 Thermal adaptation

In both the summer and winter surveys, families were asked about their thermal adaptation strategies. No options were given; instead the families just reported in freeform what they did to cope with the heat or cold.

5.2.1 Summer

The most reported coping mechanism in summer was to shower or pour water onto themselves with their clothes on, repeatedly throughout the day (Figure 7). The second most common strategy was using wet towels wrapped around their head, neck or shoulders in Zaatari and spraying the screed floors with water in Azraq. Removing carpets and sitting on the screed floor was frequently reported in Azraq, while many families in Zaatari reported sitting in the covered courtyards with screed flooring that the occupants had created between their caravans. 79% of the families kept the windows open all the time, with “dust” and “sandstorms” being the most common reason for closing windows – 61% of the time, other reasons included security and privacy (19%), feeling cold at night (13%) and bugs (7%). 50% of the families in Azraq reported having limited ability to adapt their clothing, especially women as they kept doors and windows open, while only 35% felt the same in Zaatari, this is mainly because Zaatari residents had more freedom in adapting their shelters, changing the orientation of the caravans and building extensions to create a more private space while still allowing ventilation.

5.2.2 Winter

Over 90% of the families used a gas heater as the main method of keeping warm (Figure 8). The heater was reportedly kept on for an average of 10 hours a day. In addition to using a gas heater, using blankets was cited by 40% of the families as a winter strategy; and covering the floor with a carpet by 33%. The coolth of the concrete flooring, which was desired in summer, was frequently reported as a source of discomfort in winter. Other sources of discomfort cited were gaps and draughts around the structure (68%), and the type of building materials used in the shelters (55%). Several considered the inability to use the gas heater at night due to safety concerns, or during the day due to lack of fuel, as a main reason for discomfort (18%). Families were asked whether they ventilated frequently during winter: 23% responded yes, 64% reported that they were only doing so during the day while it was sunny outside. 22% said that they maintained background ventilation by not blocking ventilation pipes or gaps in the structure, or opening an interior door/window onto a self-built and therefore draughty extension.

Some of the families had savings, work permits or were receiving help from relatives, which meant they had access to more means of adaptation, for example, buying insulation boards and additional gas cylinders. It was observed that most refugees wore many layers of clothing when indoors in winter despite this being reported as an adaptation strategy by only 15% (in Figure 8). Moreover, when asked about their movement throughout the day, it was found that on average 50% and 28% of families spent their time in semi-outdoor spaces such as shaded courtyards and enclosed external spaces; in summer and winter respectively (Figure 9); although this was reported as a thermal adaptation strategy in summer by only 18% (Figure 7).

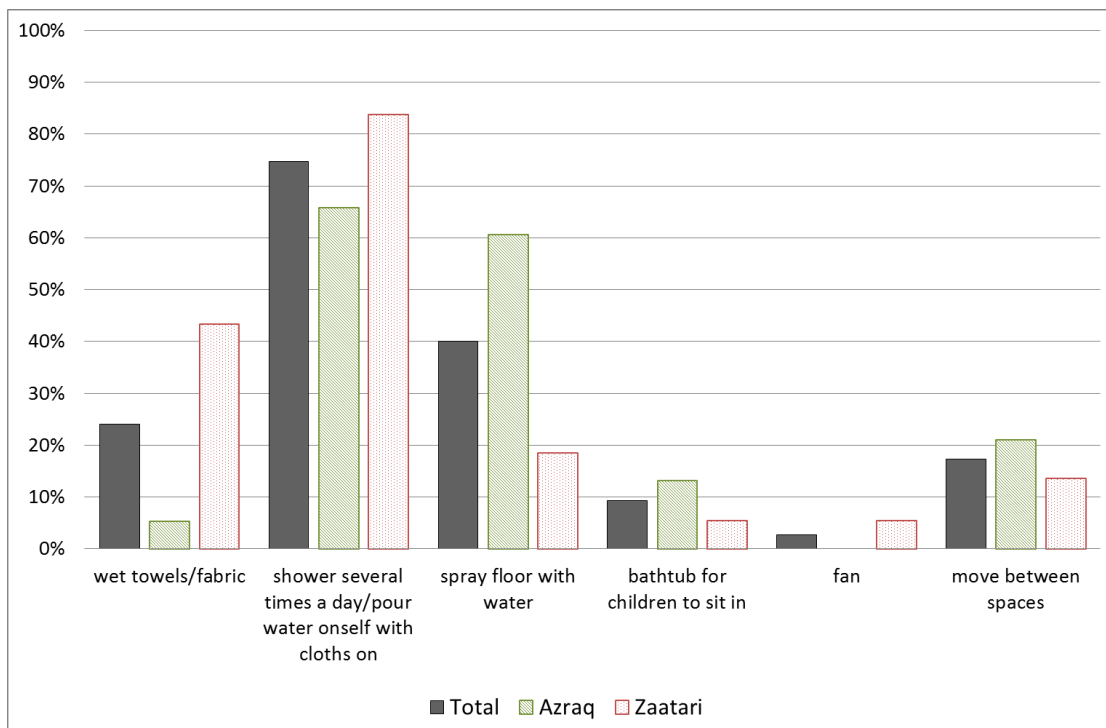


Figure 7: Thermal adaptation methods in summer. 'Total' refers to both camps combined. Showering in this case was reported as a cooling strategy, not for hygiene, and takes place with clothes on.

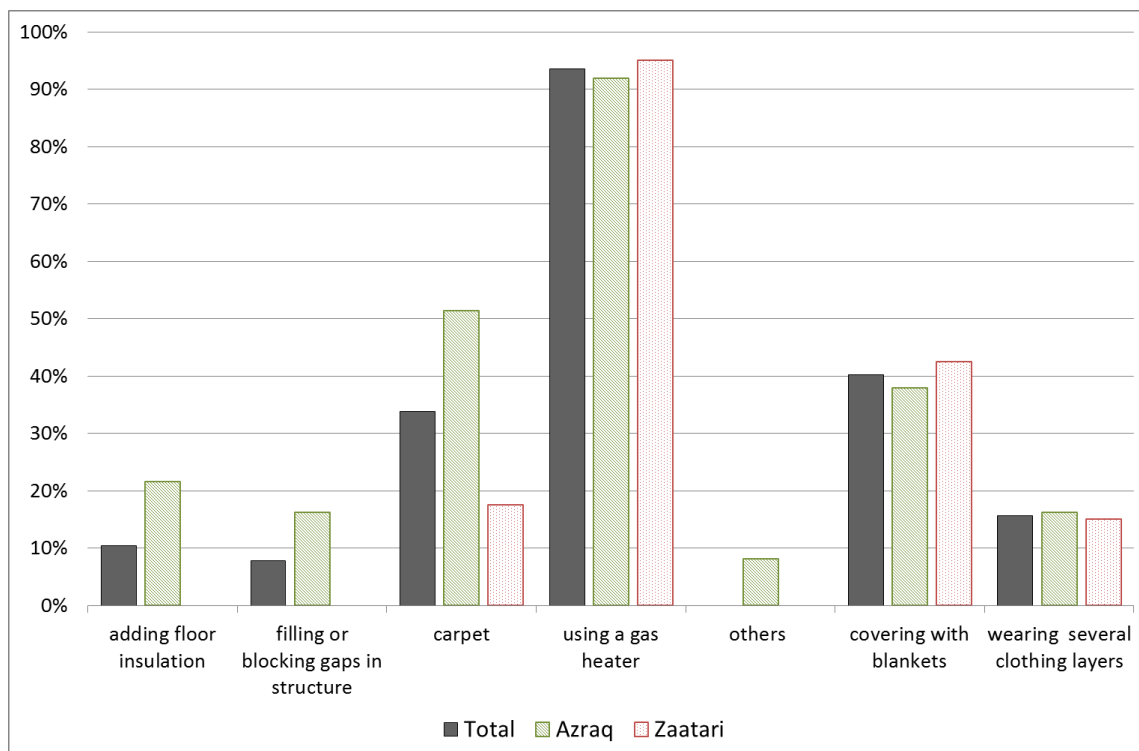


Figure 8: Thermal adaptation methods in winter, 'others' includes drinking hot drinks, sitting in the sun.

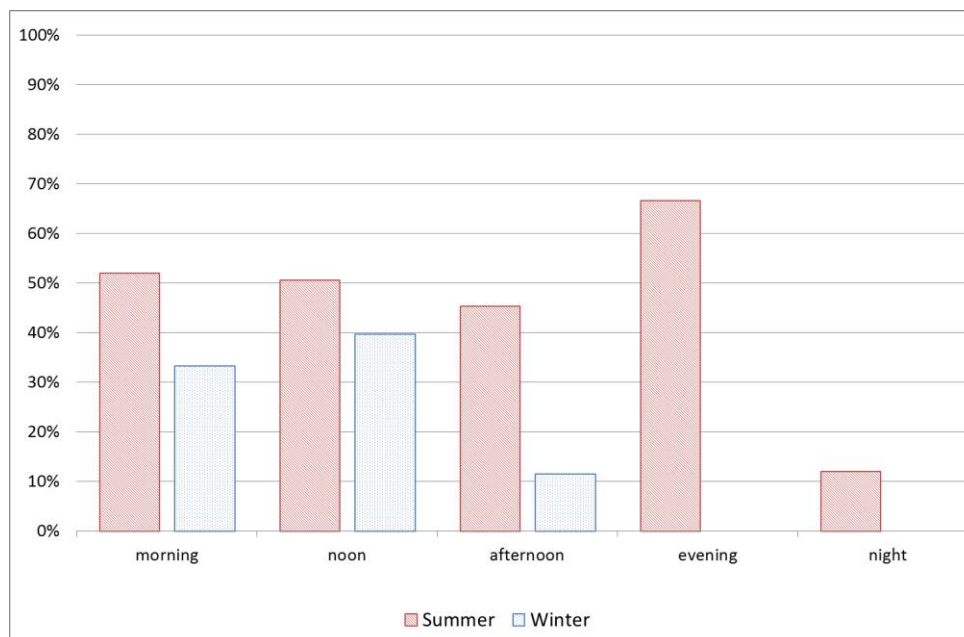


Figure 9: Time spent in the semi-outdoor spaces of the shelters; the question asked was "when at home, where do you spend your time in the morning/noon/afternoon/evening/night?"

5.3 Thermal comfort survey

In total 336 surveys were completed, 160 in summer and 176 in winter; 58% of respondents were female. The age of the respondents varied between 13 and 92 years; the mean and standard deviation (SD) was 34.6 ± 14.11 years (Table 2). In summer, the mean TSV was 1.4 for the total population of Azraq and Zaatari, which is on the warm side of the ASHRAE thermal comfort scale. In winter, the mean TSV for the total population was -0.5 which is close to neutral (0), indicating higher thermal satisfaction in winter than in summer. This could be due to the fact that the surveys were conducted during the day (9:30-15:00) when outdoor temperatures in winter were more modest, or it might be due to the greater potential for clothing adaptation in winter discussed later. All the parameters reported in Table 2, 3 and 4 are approximately normally distributed [57], except for the air speed which shows a strong positively skewed distribution, and hence its standard deviation (SD) is not useful in describing the data.

Table 2: Characteristics of male and female respondents. Data are mean \pm SD.

		No. Subject		Age (years)		Height (cm)		Weight (kg)	
		M	F	M	F	M	F	M	F
Azraq	Summer	43	41	35.4 ± 11.6	33.5 ± 13.7	171.9 ± 7.5	159.8 ± 4.3	75.4 ± 13.7	66.0 ± 12.1
	Winter	33	56	39.1 ± 14.7	35.8 ± 13.9	174.2 ± 8.3	160.8 ± 7.2	74.8 ± 14.7	71.8 ± 17.2
Zaatari	Summer	33	43	31.8 ± 13.5	32.1 ± 14.9	169.9 ± 9.1	161.0 ± 6.6	69.1 ± 12.5	68.8 ± 14.7
	Winter	32	55	35.2 ± 16.6	34.0 ± 14.3	171.3 ± 8.9	159.3 ± 5.0	77.7 ± 13.3	75.3 ± 15.6

Table 3: Thermal votes and clothing insulation values for males and females in both camps and seasons. Data are mean \pm SD.

		TSV		TPV		Clothing (clo)	
		M	F	M	F	M	F
Azraq	Summer	1.5 ± 1.2	1.6 ± 1.3	-1.4 ± 0.7	-1.5 ± 0.6	0.50 ± 0.07	0.93 ± 0.05
	Winter	-0.1 ± 0.8	-0.4 ± 0.8	0.5 ± 0.7	0.6 ± 0.7	1.20 ± 0.21	1.54 ± 0.27
Zaatari	Summer	0.7 ± 1.1	1.5 ± 1.2	-1.0 ± 0.7	-1.3 ± 0.6	0.47 ± 0.06	0.93 ± 0.08
	Winter	-0.5 ± 0.9	-0.7 ± 1.2	0.7 ± 0.7	0.8 ± 0.8	1.02 ± 0.32	1.48 ± 0.26

Table 4: Environmental parameters. Data are mean \pm SD. The minimum indoor temperature recorded was 12°C and the maximum 37°C.

		Indoor RH (%)		Indoor Av (m/s)		Indoor To (°C)		Tout (°C)
		M	F	M	F	M	F	
Azraq	Summer	22.3 ± 6.8	25.0 ± 5.2	0.14	0.11	33.3 ± 2.5	32.5 ± 2.4	33.7 ± 2.4
	Winter	42.7 ± 7.4	38.8 ± 8.6	0.00	0.00	18.9 ± 1.9	19.5 ± 2.2	13.0 ± 2.3
Zaatari	Summer	38.4 ± 6.0	37.5 ± 6.8	0.19	0.21	31.2 ± 2.3	30.8 ± 2.2	31.5 ± 3.2
	Winter	37.9 ± 6.5	37.1 ± 7.9	0.03	0.10	18.3 ± 2.0	17.9 ± 2.5	11.2 ± 1.9

5.3.1 The relationship between thermal sensation and thermal preference

It is reasonable to expect that those who vote 'neutral' on the thermal sensation scale will vote 'no change' on the thermal preference scale. While those who feel cold/warm will prefer a change in their environment. For example, a study in a naturally ventilated office building in China found that the vast majority of occupants (95%) who voted 'neutral' preferred 'no change' [31]. On the other hand, several studies have highlighted that votes on the thermal sensation and thermal preference scale may not be consistent. Indraganti et al., [58] found a preference for cooler indoor environments in southern India regardless of occupant thermal sensation votes. In hot and humid climates, Damiani et al., [59] found that 19% of those who voted neutral preferred a cooler temperature. In this study we found that in winter, there was a prevalence of 'no change' preference votes when the votes on the thermal sensation scale were on the warm side (1 to 3); while in summer 100% of those who felt 'slightly cool' preferred no change (Figure 10). This supports the "semantic artefact hypothesis" [10] that people prefer warm thermal sensations in winter and cool ones in summer. Furthermore, 68% of the people who voted 'neutral' in summer reported a preference for 'a bit/much cooler' environment while in winter 34% of the 'neutral' people preferred it to be 'a bit warmer'. This could indicate that refugees tolerate and thus adapt to their environment because they are unable to change it, but given the means they would prefer to 'improve' it. This was reinforced in the comments of the refugees where they have reported that they had come to accept their loss, and throughout the interviews, they repeatedly stressed that they were "grateful to be alive" or for having "a safe place" whenever asked about their satisfaction and preferences.

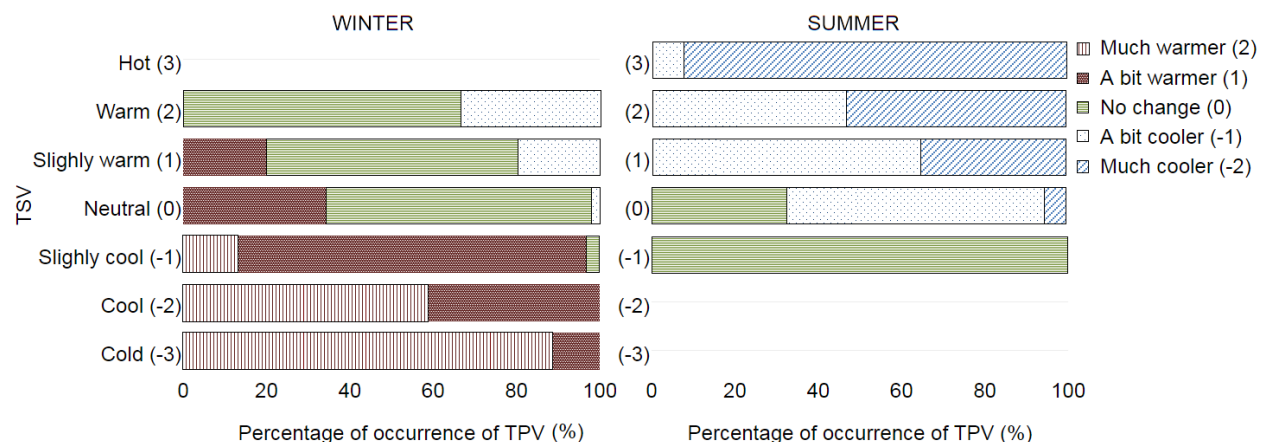


Figure 10: Distribution of TPV expressed as a percentage (%) for the different TSV in both seasons.

Figure 11 shows the cumulative percentage of wanting to be cooler (-1 and -2) and wanting to be warmer (1 and 2) against the thermal sensation scale. Both lines intersect at the neutral point. In a study by Indraganti et al., [13] they found that the "wanting to be cooler" and "wanting to be warmer" curves did not intersect at the neutral point, and the reasons given to justify the shift toward the cool side of the scale were either issues with the translation and the terminology used within the scale in Japanese, or because the survey was conducted only in summer. Humphreys et al., [45] note that translating the ASHRAE scale into different

languages results in irregularities in the way it behaves, and that such irregularities are more attributable to the exact meaning of the words used rather than the actual thermal sensation. Figure 11 accounts for both seasons, and therefore the fact that in this study the curves intersect at the neutral point is a powerful validation of our numerical approach to the questionnaire (explained in (4.1.2) and published in appendix B).

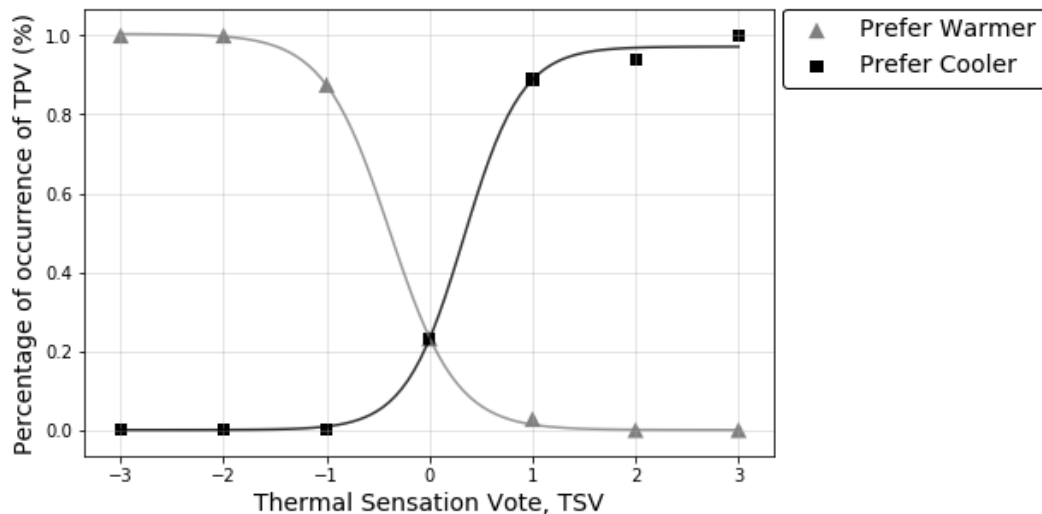


Figure 11: “Wanting to be cooler” and “wanting to be warmer” intersect at the neutral point on the thermal sensation scale. Logistic curves have been fitted to the data—with the data collated into 1°C bins.

5.3.2 The neutral temperature

We use simple linear regression (equation (4)) to derive the neutral temperature T_n for the whole population as explained in section 4.3. We use 1°C operative temperature intervals and discard intervals with only one vote. Tables 5,6 and 7 show the gradient (α) and intercept (b) of the fitted linear models together with the p-value for the gradient and the coefficient of determination (R^2). The p-value for the gradient tests the null hypothesis that the predictor (T_o) has no effect on the response variable (TSV), i.e. that the coefficient is equal to zero. A low p-value (<0.05) indicates that we can reject the null hypothesis. R^2 measures the proportion of variability in the response variable that can be explained using the predictor.

The thermal sensation and thermal preference regression lines (Figure 12) intersect with the neutral axis at almost exactly the same point and therefore give similar neutral temperatures (T_n): $22.7 \pm 0.75^\circ\text{C}$ and $23.0 \pm 0.40^\circ\text{C}$, respectively (calculated value \pm one standard error SE, Table 5).

According to the statistical assumption underlying Fanger’s model [7], 80% thermal acceptability corresponds to a TSV between -0.85 and 0.85. This assumption is the same used in the adaptive comfort approach to define comfort bands for 80% acceptability using the TSV linear regression equation [10]. By substituting ± 0.85 for TSV in the linear regression equation, the derived comfort temperature band for the whole surveyed population is seen to extend from 16.8°C to 28.5°C . The linear regression slope was $0.14/^\circ\text{C}$ for the TSV of the whole population. This is a low angled slope; other studies in hot and dry climates [22, 48, 49]

had a TSV gradient ranging from 0.13/°C to 0.25/°C. As explained earlier, less steep regression gradients indicate higher adaptability of the population.

Table 5. Linear regression.

	α	b	p-value	R^2	$T_n \pm SE(^{\circ}C)$
TSV	0.1446	-3.2762	0.000	0.855	22.7±0.75
TPV	-0.1390	3.1958	0.000	0.951	23.0±0.40

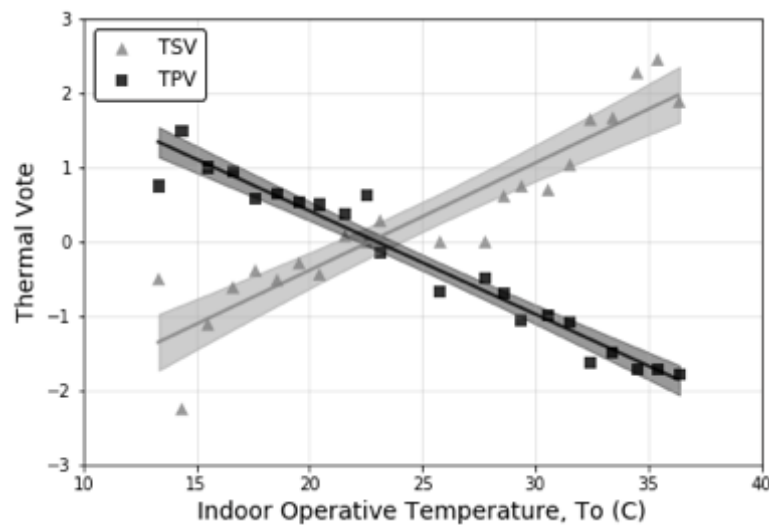


Figure 12: Linear regression models with 95% confidence bands.

5.3.3 Seasonal differences in the neutral temperature

Splitting the data into the summer and winter periods we find that in winter the gradient is less steep (Table 6), this means that people were more sensitive to changes in temperatures in summer and, therefore, summer is the season which posed more difficulties for their thermal adaptation. This might be expected, since in winter people had more means of adaptation (gas heating, clothing) than in summer (limited clothing adaptation opportunities for sociocultural reasons). The T_n calculated by using TSV for the summer season is about 5°C higher than in winter: 26.5±0.55°C and 21.8±1.30°C respectively. However, by using TPV we obtain very different results: 22.3±0.60°C in summer and 25.3±1.25°C in winter. While this could be explained by the above mentioned semantic artefact hypothesis, it should be noted that the difference we observe is much higher than the maximum 1.5K observed by De dear and Brager [10].

Table 6. Season-separated linear regression.

		$\alpha(^{\circ}C)$	b	p-value	R^2	$T_n \pm SE(^{\circ}C)$
TSV	Summer	0.2413	-6.4016	0.000	0.897	26.5±0.55
	Winter	0.1551	-3.3859	0.008	0.559	21.8±1.30
TPV	Summer	-0.1330	2.9707	0.000	0.886	22.3±0.60

Winter	-0.0967	2.4511	0.005	0.609	25.3±1.25
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5.3.4 Gender differences in the neutral temperature

Women were found to be slightly more sensitive (Table 7). This is in agreement with previous research [60, 46]. However, this was not necessarily only due to physiological differences but, in this particular context, could be attributable to differences in allowable clothing adaptation. However, in order to test if the two gradients of Table 7 are statistically significant, a multivariate linear model was computed for TSV having as predictors T_o , the gender and their interaction $T_o \times \text{gender}$. The results of the model indicate that the interaction term is statistically significant ($p < 0.05$), hence the coefficient of T_o depends on the gender.

Table 7. Gender-separated results of the linear regression analysis for TSV.

		$\alpha(^{\circ}\text{C})$	b	p-value	R^2	$T_n \pm \text{SE}(^{\circ}\text{C})$
TSV	Women	0.1584	-3.5150	0.000	0.892	22.2±0.85
	Men	0.1226	-2.7319	0.000	0.794	22.3±1.30

5.3.5 Predicted mean vote (PMV)

After calculating the PMV of each individual as described in 4.2.3, linear regression was then used to calculate the T_n and comfort bands based on the PMV. This allows us to compare it with the T_n calculated above using the actual TSV and check if the model is suitable for predicting the refugees' thermal sensation. A comparison between the predicted PMV and the actual TSV shows that the $T_n(\text{PMV})$ is 0.5K lower than $T_n(\text{TSV})$. However, the comfort band derived for ± 0.85 suggested by Fanger for 80% acceptability is 18.1°C to 26.3°C, which is 1 to 2 degrees narrower on either side than the TSV comfort bands. Fanger's model is therefore underestimating the adaptive potential of the Azraq and Zaatari population. This is expected as the PMV model has been shown to predict narrower comfort ranges by several researchers [13]. This also indicates that the PMV is not a suitable model for use under such circumstances. The slope of the PMV regression line is 0.21/°C which is much lower than Fanger's 0.33/°C [7]. By contrast, our slope for the summer season (in which people had limited means of adaptation) is 0.31/°C (i.e. close to that given by PMV) supporting the observation that the PMV is only a suitable indicator of thermal comfort when people have limited or no adaptation opportunities (Table 8).

Table 8. Linear regression for PMV.

		$\alpha(^{\circ}\text{C})$	b	p-value	R^2	$T_n \pm \text{SE}(^{\circ}\text{C})$
	Overall	0.2074	-4.6050	0.000	0.955	22.2±0.50
PMV	Summer	0.3146	-8.0401	0.000	0.988	25.6±0.15
	Winter	0.1783	-4.0062	0.000	0.830	22.5±0.70

5.3.6 Logistic regression

As explained in the methodology, we used both linear and logistic regression to analyse our data. This double approach allows us to compare our outcomes to other research papers as well as validate them by using two different techniques.

Logistic regression was conducted for the TSV following the approach used by [19, 55, 61]. This allows us to compare the comfort temperature band derived from the logistic regression model with the one predicted by the linear model. The objective variable to be modelled is therefore the thermal sensation vote, which takes ordinal values in the range of [-3, 3]. For the application and analysis of the logistic model, it is more suitable to reduce the seven categories to the three classes *cold*, *comfortable*, *hot*, with:

- $TSV < -1$ classified as *cold*,
- $-1 \leq TSV \leq 1$ classified as *comfortable*,
- $TSV > 1$ considered as *hot*.

The internal operative temperature (T_o) is the predictor since we are interested in identifying the comfort temperature bands of the occupants. It is worth noting that, while the linear methods used binned data, the logistic model is fitted by using the separate votes of the individuals, hence the dis(comfort) probabilities of Figure 13 are only shown for reference.

After the regression was computed, the probabilities (given by equation (6)) of having a hot, $P(TSV > 1)$, cold, $P(TSV < -1)$, and comfortable, $P(-1 \leq TSV \leq 1)$ vote; are then given by the following equations derived by fitting the logistic regression to the data:

$$P(TSV > 1) = \frac{\exp\{-11.1786 + 0.3437T_o\}}{1 + \exp\{-11.1786 + 0.3437T_o\}} \quad (9)$$

$$P(TSV < -1) = \frac{\exp\{4.2310 - 0.3252T_o\}}{1 + \exp\{4.2310 - 0.3252T_o\}} \quad \text{and} \quad (10)$$

$$P(-1 \leq TSV \leq 1) = 1 - \{P(TSV > 1) + P(TSV < -1)\} \quad (11)$$

All the coefficients are statistically significant at $p < 0.001$.

According to the ASHRAE thermal comfort standard 55-2013 [23], a thermal environment is regarded as comfortable when more than 80% of the occupants find it thermally acceptable; in terms of thermal sensation vote (TSV), this means that they are feeling between 'slightly cool' and 'slightly warm'. In other words, the comfort band range is the range of temperatures which correspond to a probability of having $P(-1 \leq TSV \leq 1)$ higher than 80% as predicted by the logistic model. Based on this criterion, the comfort temperature band for the occupants of Azraq and Zaatari camps spans from 17.2°C to 28.4°C (Figure 13). This comfort band is only slightly tighter than the one predicted using the linear method (16.8°C to 28.5°C).

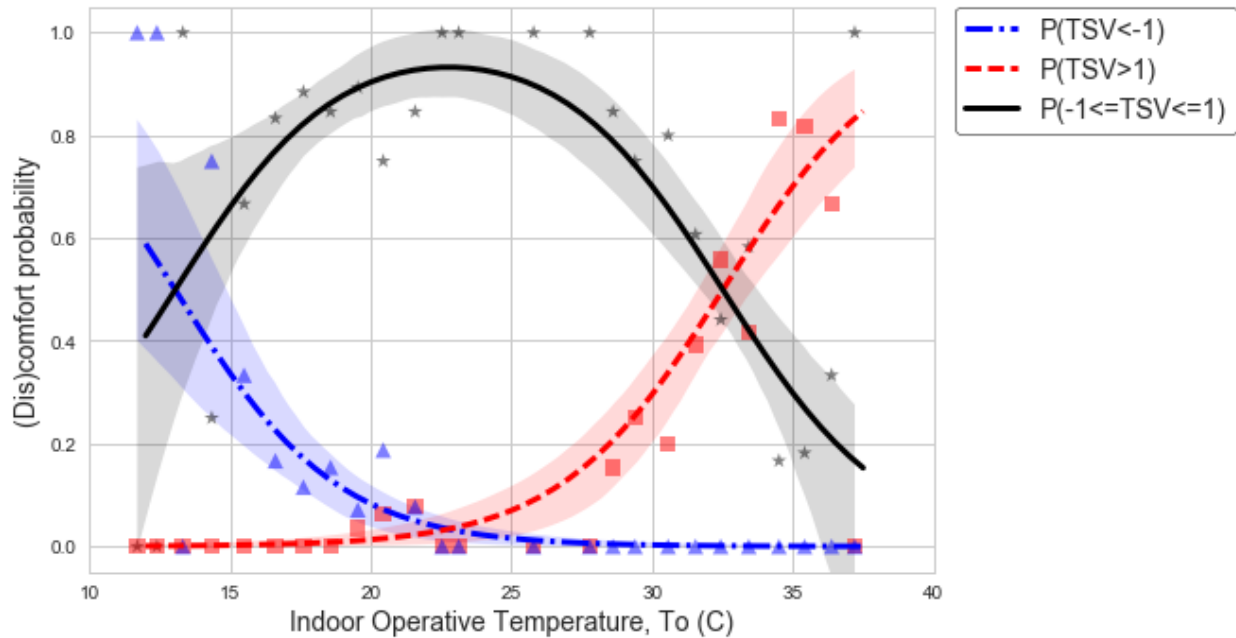


Figure 13: Dis(comfort) probability for the multinomial logistic model with 95% confidence bands. TSV-based $T_n = 22.8^\circ\text{C}$.

5.3.7 Multiple logistic regression

Simple logistic or linear regression assumes that a single variable (in our case T_o) explains the response of the population. However, it is likely that other variables play a part, and knowing their relative influence would be of use in informing the design of more appropriate shelters. A multiple regression framework can be used to calculate the influence of each variable.

The selected potential predictor variables were:

- T_a (internal air temperature, $^\circ\text{C}$),
- RH (internal relative humidity, %),
- T_g (internal globe temperature, $^\circ\text{C}$)
- I_{cl} (clothing insulation, clo),
- V_a (internal air speed, m/s),
- MET (metabolic rate of the subject, met),
- SEX (0=male/1=female),
- AGE (age of the subject, years),
- CAMP (0=Azraq/1=Zaatari).

T_o was not used because it includes some of the other variables (T_a and V_a) in its definition. Prior to the analysis, the continuous variables were standardized by subtracting the mean and dividing by the standard deviation; this makes it possible to directly compare the dimensionless coefficients generated (Table 9 and 10).

Table 9. Results of the multiple logistic regression (summer).

coef	SE	p-value	[95.0% conf. int.]
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Intercept	-2.4804	0.32	0.000	-3.10	-1.86
T _a	2.9522	0.41	0.000	2.14	3.76
V _a	-0.7506	0.23	0.001	-1.20	-0.30
I _{cl}	0.7335	0.31	0.018	0.13	1.34

Table 10. Results of the multiple logistic regression (winter).

	coef	SE	p-value	[95.0% conf. int.]	
Intercept	-4.0257	0.58	0.000	-5.17	-2.89
T _a	-2.5446	0.57	0.000	-3.66	-1.43
V _a	0.5951	0.21	0.004	0.19	1.00

As would be expected, T_a was found to be the most important predictor of discomfort in both summer and winter (Table 9 and 10). CAMP, AGE, SEX and RH were found not to be significant predictors, this means that occupant thermal perception does not statistically differ between the camps and that AGE, RH and SEX does not influence TSV. It is interesting that relative humidity in both camps and during both seasons is extremely low, this would facilitate thermal adaptation, as the cooling due to sweating is enhanced [62]. I_{cl} was found to be a significant predictor for hot discomfort (i.e. in summer) but not for cold discomfort (i.e. winter), while V_a is a statistically significant predictor for both. At increasing air speeds the discomfort temperature increases for both women and men in winter, for example, if air temperature remained constant, a 0.1 m/s increase in air speed, means a 13% *increase* in the probability of having a cold vote. While by holding I_{cl} and T_a fixed, a 0.1m/s increase in V_a, means a 17% *decrease* in the probability of having a hot vote (Figure 14). High I_{cl} values in summer increase the thermal sensation vote of occupants (Figure 14). This suggests that future shelter design should allow occupants to have the privacy needed for adapting their clothing to minimum desirable levels, for example by the covering of windows, and yet not restrict air movement—a potential design tension.

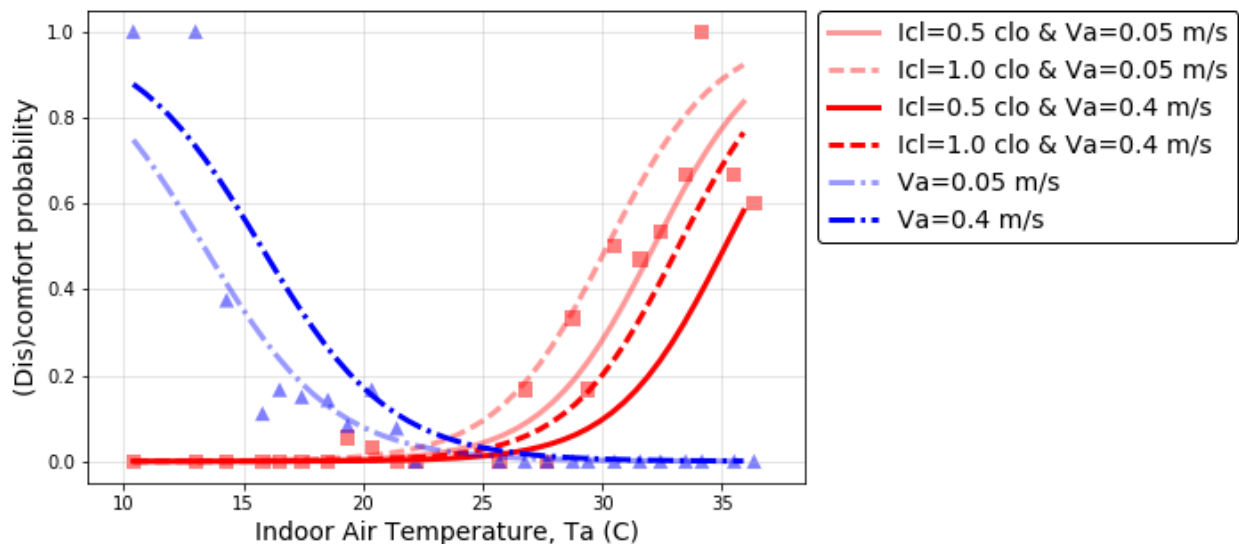


Figure 14: Dis(comfort) probability for 1°C operative temperature intervals and fitted multiple logistic models for the probability of having a hot (red) and cold (blue) vote at different I_{cl} and V_a values.

That I_{cl} is a predictor of comfort is not surprising as it is widely accepted that clothing levels have a significant influence on peoples' thermal sensation [23, 39, 42]. A change of 1clo corresponds to approximately 6°C in the neutral temperature [23]. (The adaptive thermal comfort theory assumes that occupants are able to adapt to their environment by changing their clothing [23].)

We found that an increase of 0.5 in I_{cl} corresponded to a 53% increase in the probability of having a hot vote, assuming the air temperature and air speed remained constant. The limited ability, especially of female respondents, to adapt clothing in summer undoubtedly contributed to their higher sensitivity shown in 5.3.4. In winter, respondents were dressed for the outdoors even while being indoors, wearing multiple layers and sometimes even outdoor coats or jackets, this explains the high I_{cl} values shown in Figure 15. In winter, the need to dress for the outdoors while being indoors in order to keep warm, not only illustrates aspects of the current shelter designs but has also probably contributed to some of the neutral votes given, despite the low temperatures recorded. A study in central southern China in winter [63] obtained a neutral temperature of 11.5°C for rural populations and 14°C for urban populations. The study attributed such low neutral temperatures to the high mean I_{cl} (2 clo) of the surveyed population, in addition to psychological adaptation. A study in Iran [22] showed a low correlation between T_o and clothing insulation in summer but a greater correlation in winter due to similar cultural issues as those faced in this study; in which people were dressed to the minimum socially acceptable limit in summer, while in winter they were freer to choose the level of clothing that would make them comfortable.

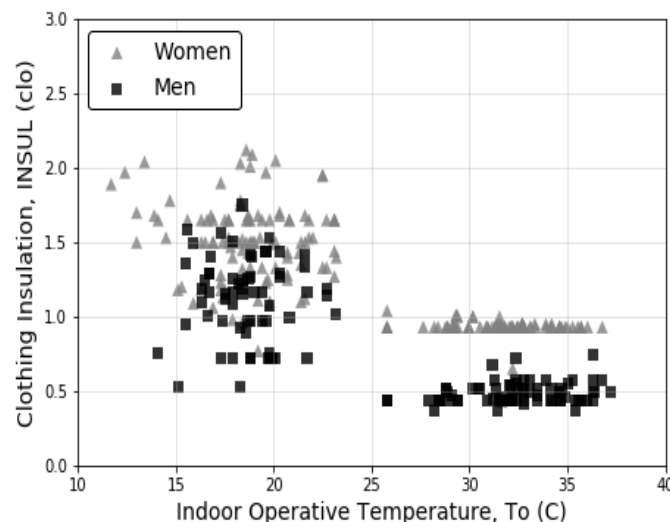


Figure 15: Female clothing insulation diversity was very restricted in summer, with almost no variations in I_{cl} . In addition, I_{cl} of women in summer is twice that of men.

5.4. Comparison with the Adaptive Standards

It is interesting that the T_n calculated using linear regression for TSV (22.7°C), for TPV (23°C), and using multinomial logistic regression for TSV (22.8°C) are so close, approximately 23°C. However, one of the main implications of the adaptive theory is that thermal neutrality is not the same between seasons, and that it is expected to be higher in summer and lower in winter, this is exactly what we see when we seasonally separate the data. Indeed, the T_n we calculated for each season fits well with the ASHRAE-55 comfort bands using the historical outdoor monthly mean temperature of the two locations (Azraq and Mafraq obtained from [27]) (Figure 16).

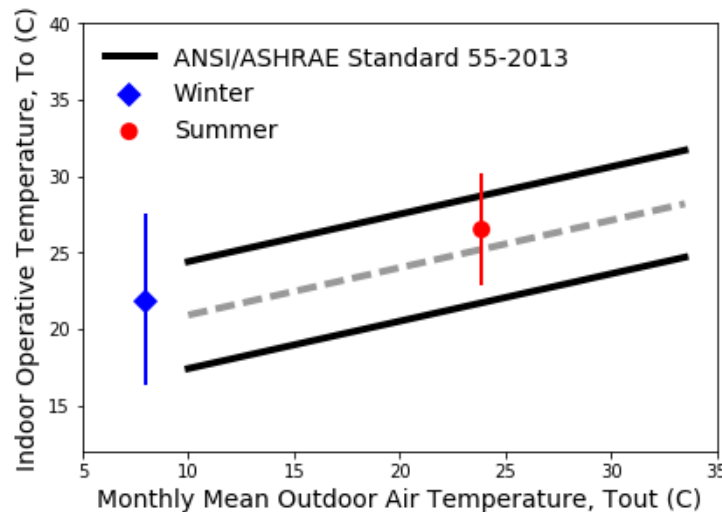


Figure 16: Neutral temperature and comfort limits found in this study in relation to the ASHRAE adaptive model.

6. Conclusions

This work represents the first such work with this understudied population of refugees living in camps; in addition, we publish a new questionnaire for use in foreign languages (see appendix B). We believe that our approach to conducting a survey, where the correct meaning of the ASHRAE scale terminology was achieved through a numerical approach rather than using a description, could be used in other languages where literal translation from English could not be used. In addition, given the use of interviews, rather than questionnaires completed by the respondents unaided, added rigour by giving the potential to explain the meaning of the questions and stressing that the questions related to the present moment, rather than feelings of comfort in general over past week or month. Plotting the TPV and TSV cumulative probability distributions against each other, showed that our new survey method gives the same neutral point for both approaches, and neutral temperatures within 0.3°C of each other. Thereby strongly validating our approach and solving the issues previous researchers reported with respect to translating the comfort scales into other languages.

The main findings are:

- Provision of security and safety were cited as the most important considerations in the design of a shelter, then thermal comfort, then privacy. 75% of the families were satisfied or very satisfied with the safety of their shelters.
- Fanger's predicted mean vote model was found to underestimate the adaptive potential of the population, with the refugees more adapted to higher temperatures than predicted by the PMV. This suggests that the PMV is not a suitable model for use under such circumstances.
- The majority of families reported that they found their shelters to be unbearably hot in July and August, while they also found it freezing in winter especially at night.
- Overall, a higher thermal satisfaction level was reported in winter than in summer.
- 50% of the families in Azraq reported having limited ability to adapt their clothes, especially women; while only 35% felt the same in Zaatari. This is mainly because Zaatari residents had more freedom in adapting their shelters to create a more private space while still allowing ventilation.
- The coolth of the concrete flooring was desired in summer, but was frequently reported as a source of discomfort in winter. Other sources of discomfort cited were gaps and draughts around the structure (68%), and the building materials used in the shelters (55%).
- Most refugees wore many layers of clothing when indoors in winter and used evaporative cooling to achieve comfort in summer—including showering with clothes on.
- All three assessments and analysis methods gave the same neutral temperature (T_n), 23°C.
- When T_n was calculated separately for each season using linear regression for TSV, the summer T_n was 4.7K higher than winter, fitting well with the ASHRAE adaptive model.
- The summertime T_n was found to be 4.2K lower when calculated using the TPV linear regression equation than with TSV. While in winter it was 3.5K higher when using TPV. Such discrepancy between the T_n (TSV) and T_n (TPV) for each season is much higher than that observed in literature and therefore could not be explained by the “semantic artefact hypothesis” alone.
- The comfort band found using logistic regression ranged from 17.2°C to 28.4°C – suggesting a significant adaptability of the refugees, but not one equal to the temperature range found on site.
- The level of clothing and the air speed were found to highly influence the TSV.
- Tensions between the need for ventilation, privacy, security and avoiding sand ingress were identified, and this points to a need to re-evaluate shelter ventilation in general. However, given the extreme conditions recorded, natural cross ventilation alone will not be sufficient in achieving summer comfort. Combining this with the observation that, due to safety and lack of resource, the refugees have no means of heating at night, a shelter solution that successfully includes better insulation, and possibly thermal mass would seem important.

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The social and thermal survey data used in this work can be accessed from <https://doi.org/10.15125/BATH-00424>

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Appendix A: Tables

Table A1: Instruments specification

Measurement	Type	Accuracy	Resolution	Range
Interior T_a , Interior T_g , Interior RH	Extech HT30 Heat Stress WBGT (Wet Bulb Globe Temperature) Meter	$\pm 1^\circ\text{C}$, $\pm 2^\circ\text{C}$, $\pm 3\%$	0.1°C 0.1°C 0.1%	0 to 50°C , 0 to 80°C , 0 to 100%
Interior V_a	ATP Hot wire anemometer	$\pm 5\%$ of reading $+0.1\text{m/s}$	0.01m/s	0.1 to 25m/s
Weather station	Radio-Tech temperature and humidity sheilded sensor	$T_a < \pm 0.3\text{K}$ RH < 3%	0.01°C 0.01%	-10°C to $+55^\circ\text{C}$ 0 to 100%
	WindSonic ultrasonic anemometer	Wind Speed $< \pm 2\%$ Direction $< \pm 3^\circ$	0.01m/s 1°	0 to 60m/s 0 to 359°
	Kipp & Zonen SP Lite Silicon Pyranometer	$< 10\%$		0 to 2000 w/m^2 ($T = -30^\circ\text{C}$ to $+70^\circ\text{C}$)

Table A2: ASHRAE standard sensation and preference scales and suggested Arabic translation

Numerical scale	ASHRAE sensation scale	ASHRAE Preference scale	Arabic sensation scale (Levantine dialect)	Arabic preference scale (Levantine dialect)
3	hot		حار جدا (كثير مشوب)	
2	warm	much warmer	حار (مشوب)	ادفي بكثير (كثير ادفي)

1	slightly warm	A bit warmer	حار قليلا جدا (شوي مشوب)	ادفي بقليل (شوي ادفي)
0	neutral	no change	حيادي (حيادي)	لا تغير (لا تغير)
-1	slightly cool	A bit cooler	بارد قليلا جدا (بارد شوي)	ابرد بقليل (شوي ابرد)
-2	cool	much cooler	بارد (برد)	ابرد بكثير (كثير ابرد)
-3	cold		بارد جدا (بارد كثير)	

Appendix B: The adapted thermal comfort questionnaire published in English to allow translation to other languages (Levantine dialect):

Part 1: Thermal Sensation

Thermally speaking, at this moment in time, are you feeling absolutely neutral or feeling a sensation of heat or coolth (no matter how little)

a	neutral	(حيادي)
b	a sensation of heat	(شعور بالثوب)
c	a sensation of coolth	(شعور بالبرودة)

if b, from scale of 1 to 3 how hot are you feeling, with one being a little bit (شوي) and 3 being a lot (كثير)

1 2 3

if c, from scale of 1 to 3 how cold are you feeling, with one being a little bit (شوي) and 3 being a lot (كثير)

1 2 3

Part 1 Summary:

Answer	Numerical scale	Corresponding ASHRAE scale
b3	3	Hot
b2	2	Warm
b1	1	Slightly warm
a	0	Neutral
c1	-1	Slightly cool
c2	-2	Cool
c3	-3	Cold

Part 2: Thermal Preferences

1) At this moment in time, do you prefer a change or no change in your thermal environment

a	no change	(لا تغير)
b	change/toward warmth	(تغير للدفء)
c	change/toward cold	(تغير للبرد)

2) if b, from scale of 1 to 2 how much warmer would you like it to be compared to NOW

1	a little bit	(شوي)
2	a lot	(اكثر)

3) if c, from scale 1 to 2 how much colder would you like it to be compared to NOW

1	a little bit	(شوي)
2	a lot	(اكثر)

Part 2 Summary:

Answer	Numerical scale	Corresponding Preference scale
b2	2	Much warmer
b1	1	A bit warmer
a	0	No change
c1	-1	A bit cooler
c2	-2	Much cooler